Measuring Professional Teams' Information Sharing Behaviour

Juliánna Katalin Soós
soosj@erg.bme.hu

Márta Juhász
juhaszm@erg.bme.hu

Balázs Péter Hámornik
hamornik@erg.bme.hu

Budapest University of Technology and Economics
Department of Ergonomics and Psychology
Egry J. utca 1, Budapest, H-1111 Hungary

ABSTRACT
Professional teams are highly differentiated from other teams through exclusive membership of expert specialists, where the team members have to integrate their specific knowledge in order to operate the technologically complex system on team level. In the present study, we aimed to describe Nuclear Power Plant (NPP) team members' communicative behaviour under different levels of task load and to focus on the predictability of team performance on the bases of communication. We had observed and analysed 16 NPP operator teams' information sharing behavior in a simulator environment. Video recorders of operators' activity during a selected scenario have been used for collecting and analyzing data. According to our analyses, several specific communication dimensions were related to performance.

Author Keywords
Team work, team cognition, communicative behaviour analyses, and different level of task load.

ACM Classification Keywords
H5.3. Group and Organization Interfaces: Synchronous interaction.

INTRODUCTION
In recent years the technological developments has risen significantly, which led to the spread of complex operations in the field of work. Additionally, the increased complexity of workflow and tasks necessitates a multioperator environment. No wonder that professional teams have started to play a critical role in complex operations, where two or more members having specific roles, responsibilities will be able to accomplish tasks that are too complex for individuals.

Professional teams execute brief operations or missions repeatedly under technologically complex conditions, which requires extended professional, vocational training and preparation from the organization as well as from the individuals [4,1].

We aim to examine Nuclear Power Plant (NPP) operator teams work in high risk environment, where it is expected to avoid irreversible failures that endanger human life or cause material damage. High risk environments are environments in which there is a more than normal chance of damaging one's own life, the life of others or material property [4]. The operator team is exposed to face with several environmental task load factors, such as noise, prolonged work, work shifting, complexity, novelty, uncertainty and time pressure, which may have significant effect on the team performance [7]. As long as operator teams have to work under various, changing condition of task load it is important to develop mutual coping strategies, which constitute efficient information sharing activity, coordination, cooperation, terminally communication.

The main question in studying operator teamwork is how the team members representing different special fields are able to operate and manage a technically complex system, in a high risk environment. According to theoretical approaches of team cognition each individual has two different models: *team mental model*, referring to the collective task and team relevant knowledge (roles and responsibilities, knowledge of teammates, skills, abilities, beliefs), and *team situation model*, describing team collective understanding of the specific situation. These team level knowledge constructs guide the team in assessing and interpreting cues and patterns of the current situation [1,2,3,5]. Furthermore team level knowledge structures allow team members to reliably predict each other's needs, actions and to act on these without explicit communication. In this way the team process, specially communication is the most appropriate means to prepare for a coordinated cooperation in emergencies, non routine problems creating a shared understanding of the situation [8]. The information sharing activity is essential for the coordination within the team, and for the way how a team handles and manages difficult, high task load situations, where the prompt, accurate information flow is crucial especially in a technically complex environment such as NPP. In this sense appropriate information sharing activity, communication can reduce and manage both the causes and the consequences of high task load.

Our study focused on the NPP operator teams' information sharing activity, namely communication, in order to identify and understand those key communicative behaviours that support the joint assessment of the current situation and help to develop adequate team strategies to face unpredictable emergencies.

METHODS

The data collection was based on operator team interactions analysis in the Simulator Centre of a Hungarian Nuclear Power Plant. Since communication is the central factor of our research, the empirical studies of a "lively" interaction can best be carried out by analyses of carefully chosen simulator sessions. The Hungarian NPP Simulator Centre may be considered as a realistic, high-fidelity tool that is widely used in training and examinations creating the required level of face-validity to be relevant for real life situations. The Nuclear Power Plant's operator teams consist of four professional fields requiring the interaction of six members: Unit Shift Supervisor, Reactor Operator, Turbine Operator, Field Operator, Unit Electrician, and Shift Leader. Data from 16 operator teams' interaction have been collected. Each team had to follow the same scenario; however, the operator's reaction may have led to some slight differences. Choosing the simulation, we took into consideration that the scenario had to be oriented toward communication: in this way, all team members had to be involved in solving the control task. Possessing complementary knowledge they had to share information with each other to manage the problems occurring during the simulated malfunctions.

In order to provide a complete picture of simulation the scenario will be described briefly ("Failure of one turbine unit"): according to the annual schedule used by instructors, a live switchover test needs to be performed, while an unjustified operation of the turbine protection occurs resulting in the failure of one turbine unit. The failure of the equipment is followed by the malfunction of the primary circuit pressure control, creating a condition that also needs to be managed. The mean duration of scenario is about 35 minutes. The scenario was divided by the instructors into 3, according to the level of task load (see Table 1).

Performance Evaluation

The performance scores were made by the instructors' evaluation, both at individual and collective levels. The individual performance was based on the evaluation how the role related tasks were accomplished, using the 3-point Likert scale (1 – poor, 2 – medium, 3 - excellent). The team

Phases of scenario	Estimated level of task load
Phase 1	*Moderate* level of task load
Phase 2	*High* level of task load
Phase 3	*Moderate* level of task load

Table 1. Phases of scenario according to the estimated level of task load.

performance was assessed by the instructors' impression about the teams' efficiency under the different phases of the scenario using the same 3-point Likert scale. Eliciting data from performance assessments we developed four team performance categories:

- Excellent team: the whole team performance was evaluated excellent, through all the phases of the scenario.
- Medium team: the team performance is medium continuously through all the phases of the scenario.
- Unbalanced team: the team performance was varying from excellent to poor through the scenario.
- Poor team: the team performance was evaluated steadily as poor through the complete scenario.

Video records of operators' activity during the selected scenario have been also used for collecting and analyzing data. In order to keep the operators' real life behaviour the instructor informed them at the beginning of the simulator study about video recordings during the ongoing training session, but they did not know exactly which of the programmed scenarios would be videotaped. Video recordings were made with the operators' joint consent.

All the recorded conversation of the operators was transcribed in chronological order, identifying the operators' verbal utterances. Difficulties occurred in transcribing videotapes due to communication density during some period of the interaction, much simultaneous conversation flow between members, additionally we had to face with a noisy control room environment. For all these reasons we have few blind points in the transcribed videotapes, where the speaker of some utterances cannot be identified properly.

Communication Analyses

In our study we aimed to capture some relevant task specific aspects of NPP team's information gathering and processing behaviour. In order to capture the most relevant task-oriented aspect of teams' information sharing activity some task specific communication dimension have been developed expanding and specifying the communication dimensions used in similar environments (Conversation Analysis; Speech Act Type-inventory for the Analyses of Cockpit Communication, STACK [6]). The final major task-oriented communication dimensions were the following groups:

Information Collecting Question

The aim of the question is information acquisition, for example asking about certain indicators or resources. This can be formulated in the following two ways:

- *Open Question Information*: The question is addressed in order to complete the proposition with information; therefore it is likely to receive a long answer. It usually starts with words like *what, when, who*, etc.
- *Closed Question Information*: The aim of this question is verification, to judge the truth of a position; therefore the answer is expressed with either a single word (yes, or no) or a short phrase. For example "*Can we start the program*?"

Information Providing

The team members inform each other about some relevant aspect of the mission related to human or technical indicators. This may be grouped into three categories according to the time focus:

- *Information Providing Past*: The speaker informs the addressee about technological information, certain indicators that happened in the past, or about the crew's past status, personnel resources in the past.
- *Information Providing Present*: The speaker informs the addressee about some actual, present technological information, certain indicators, or about the crew's present status, personnel resources.
- *Information Providing Future*: The speaker informs the addressee about some technological information that may change in the future, foretells about certain indicators, or about his intentions and future actions.

Affirmation

It is the manifestation of two-way communications. It may be formulated in two ways:

- *Simple Affirmation*: Answers to yes/no question or commands. For example affirmations, acknowledgements, acceptances, answer such as *'yes', 'no', 'ok', 'good'*.
- *Affirmation with Information*: A feedback, reinforcement on a status report or information, or command completed with additional information.

Coherence Analyses

The anchored point of the *coherence analyses* was the new thought (that can be a question, information, etc.) initiated by one of the team members. The main condition of the coherent conversation is *the turn-taking*, taking up this thought, the interlocutor develops a new question, information or command related to the previous information. Otherwise, if an initiated thought is not taken up by any of the team members, it will be considered as a *thought without turn taking.*

Two independent evaluators rated the teams' transcribed information flow, based on the communication dimensions described above.

Ethical Statement

The research has been authorised by the Management of the Hungarian Nuclear Power Plant. All the research participants were informed about the research including the videotape recordings and evaluation measurements.

RESULTS

Appropriate information collection and distribution allows the team to understand better the situation, helping to build a shared conceptualization of the faced problems. According to our analyses, several specific communication dimensions were related to performance both on individual and team level. Particular forms of questions proved to be the best way to dispel uncertainties, and to realize safe communication. Our results revealed that the excellent performing teams use fewer open information collecting questions than the lower performing teams ($F= 4.690$, $p<0.05$). The frequent use of open questions suggests that when lower performing teams express their questions, they have less information, knowledge about the environmental cues, so they formulate the question in a less complete form, being unable to face the challenging of situation. The open questions are incomplete and force the addressee to use the cognitive resources to complete the proposition.

For the efficient information flow between team members it is also important to answer the supposed question, to provide the information in timely manner. The unbalanced teams show the highest communication density, regardless of the time orientation. These teams use the more frequent information providing activity about the present ($F=7.109$ $p=0.005$), past ($F=4.779$ $p<0.05$) and future ($F=1.337$, $p>0.05$) as well compared to excellent, poor and average performing teams. High density of communication without any special focus indicates the failure to capture the most relevant aspect of the ongoing episode. The results indicate that excellent performing teams focus on the present during their information providing activity, orient least of all about the past. The high performing team's communication is focused on the status, attributes, and dynamics of relevant actual elements in the environment, involving the processes of monitoring, cue detection, perception which leads to the awareness of their current status. It is also important to use the relevant information to project future situations in accordance with the team's goal.

The indicators of efficient communication include also confirming the received information. The use of simple affirmation helps the team to clarify and acknowledge the received information, in this way to establish an accurate shared understanding of the situation. Conversely the affirmation completed with additional information will overload the cognitive resources of both the information provider and receiver. Although the differences are not significant, the results can be regarded as a tendency that describes excellent performing teams using more simple affirmations and fewer affirmations with information, conversely with the low performing teams, where team members exchange more affirmations with information. The result indicates the need for a clear information change that helps to establish accurate team knowledge, instead of creating an interference with additional, not so relevant, information.

When analysing the communication under different level of task load, we observed the tendency of decreasing communication density during high task load, furthermore the increasing communication after high task load. Generally it can be concluded that as the task load increases the frequency of communication dimensions decreased. During high task load the communication is severely impeded, which can be explained by the operators' overloaded cognitive resources. The unexpected problems, failures intensively load the team members' cognitive capacity, being unable to share their attention between the accomplishment of the task and communication. Furthermore as the allocated resources disengaged, the collective need to process the causes and the consequences of unexpected event resulted in more frequent communication. It has been also explored that the poor teams' conversations indicate an incomplete flow of information between team members. Comparing the coherence indicators of excellently and poorly performing teams' dialogue, it has been explored that the poor teams' conversations include more thoughts without turn-taking ($t=5,506$, $p<0,05$), and less thoughts with turn-taking ($t=4,069$, $p=0,05$). The coherent information flow between team members proved to be an efficient communication strategy to attain high performance. Coherent communication means that the team members are aware of the information distributed by others, and react to the received information (either with a simple affirmation, or with a question, or with additional information transfer), creating a semantic connection in the information sharing activity. In this way coherent communication is one of the key elements of the effective establishment or modification, fine tuning of accurate and complete team knowledge.

CONCLUSION

The study considers some specific aspects of information sharing behaviour that could be directly linked to establishing team knowledge, such as using open and close information questions, affirmations, information provision, and coherence of information flow. The use of effectively formulated information collection utterances, the development of a well established effective communication strategy that focuses on the ongoing events and projecting the environmental cues to future situations, affirming the received information could all help the team to build, modify accurate team knowledge and to improve team performance. Future research should more thoroughly investigate the characteristics of such information sharing behaviour across different high risk environment teams (such as medical team, cockpit team), where the teams have to operate in highly standardised settings under various task load. The future work should go also beyond communication, studying other team processes, such as coordination, decision making, and also capturing the professional knowledge structures, mental model, or situational awareness at both individual and team levels.

REFERENCES

1. Cooke, N.J.-Salas, E.-Cannon-Bowers, J.A., Stout, R. Measuring team knowledge. *Human Factors, 42*, (2000), 151-173.
2. Cooke, N.J.-Salas, E.-Kiekel, P.A.-Bell, B. Advances in measuring team cognition. IN E. Salas and S. M. Fiore (Eds.), *Team Cognition: Understanding the Factors that Drive Process and Performance*, Washington, DC: Am. Psych. Assoc. (2004), 83-106.
3. Cooke, N.J.-Gorman, J.C. Assessment of team cognition. In P. Karwowski (Ed.), *2nd EDITION-International Encyclopedia of Ergonomics and Human Factors*, UK: Taylor & Francis Ltd., (2006), 270-275.
4. Dietrich, R.-Childress, T.M. *Group interaction in high risk environments*. The GIHRE Project. ASHGATE, Burlington, 2004.
5. Klimoski, R.J., Mohamed, S. Team Mental Model: Construct or Metaphor. *Journal of Management*, *20*, 2 (1994), 403-437.
6. Krifka, M. Structural Features of Language and Language use, In: Dietrich, R., Childress, T.M. *Group interaction in high risk environments*, The GIHRE Project. ASHGATE, Burlington, 2004.
7. Mumaw, R. J. The effects of stress on NPP operational decision making and training approaches to reduce stress effects, (NUREG/CR-6127). US Nuclear Regulatory Commission, 1994.
8. Sexton J.B., Helmreich R.L. Analyzing cockpit communications: The links between language, performance, error, and workload. In *Proceedings of the Tenth International Symposium on Aviation Psychology*, (1999) 689- 695.